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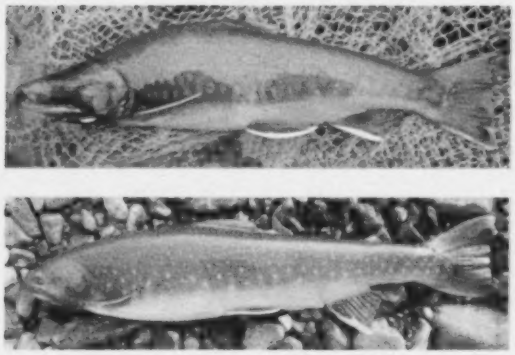
Central and Arctic Region
Canadian Science Advisory Secretariat
Science Advisory Report 2016/055

ASSESSMENT OF DOLLY VARDEN FROM THE BABBAGE RIVER, YUKON TERRITORY 2010–2014



*Male (top) and female (bottom) anadromous Dolly Varden (*Salvelinus malma*) in spawning condition (by C. Gallagher).*

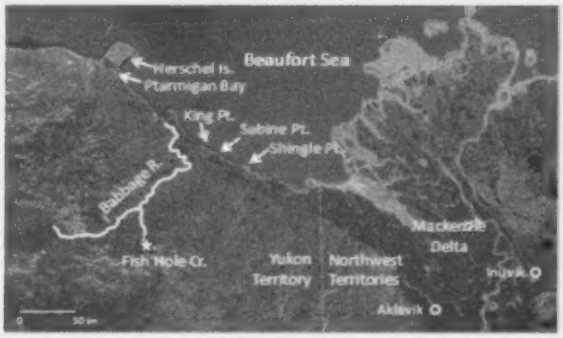


Figure 1. Map of the Babbage River showing the spawning and overwintering area (star) in Fish Hole Creek, and coastal harvesting locations along the Beaufort Sea coast (arrows).

Context:

*The Babbage River is located within the Inuvialuit Settlement Region (ISR) in the Yukon Territory. Dolly Varden (*Salvelinus malma malma*) from this system are fished by Inuvialuit beneficiaries during the summer along the Beaufort Sea coast. Dolly Varden fisheries in the ISR are co-managed under an Integrated Fisheries Management Plan (IFMP) whose signatories are Fisheries and Oceans Canada (DFO), Fisheries Joint Management Committee, Gwich'in Renewable Resources Board, and Parks Canada Agency. The West Side Working Group, the co-management body that makes recommendations for harvest levels for Dolly Varden stocks in the ISR, has supported research activities that facilitate implementation of the IFMP, including studies to monitor harvest levels and assess population status.*

Recent population studies (e.g., abundance estimates, biological and genetic sampling) and coastal harvest monitoring activities allow for a comprehensive assessment of this stock. Data from research conducted on the Babbage River and along the Beaufort Sea coast between 2010 and 2014, with selected data from previous years, were used to assess the population. The science advice will be used to inform co-management partners on the status of Dolly Varden from the Babbage River and the current estimated level of harvest.

SUMMARY

- Based on mark-recapture studies, the estimated population abundance of Dolly Varden ≥ 365 mm from the Babbage River ranged between 5,861 and 6,553 between 2010 and 2012.
- The estimated count of Dolly Varden ≥ 365 mm from the Babbage River using a DIDSON sonar was estimated to be between 2,839 and 3,119 in 2011.

Canada

- Biological information collected annually from seining at the spawning and overwintering area at the end of September between 2010 and 2014 consistently demonstrated similar median length with a wide range of sizes, a high proportion of large fish (≥ 550 mm), and a large composition of spawners (≥ 40%). The population demographics were similar to a sample collected in 1987.
- Biological data from the mark-recapture studies indicated females spawned in consecutive-years more often than did males. The growth of Dolly Varden based on the recapture of tagged fish has increased compared to the early 1990s.
- Genetic mixed-stock fishery analysis of samples collected along the Beaufort Sea coast between 2011 and 2014 indicated that Dolly Varden from the Babbage River were harvested at multiple locations along the Canadian Beaufort Sea coast.
- At Herschel Island and Shingle Point, locations where the majority of the harvest occurs, Dolly Varden from the Babbage River contributed between 2 and 14%, and 30 and 89% of the catch, respectively, between 2011 and 2014.
- It is estimated that the harvest rate in Canadian waters of Dolly Varden from the Babbage River in Canada from 2011 to 2014 ranged between 1.2 and 7.5%. The total harvest rate is unknown due to the absence of information from Alaska.
- Estimates of effective population size determined using genetic data suggest there are no immediate conservation concerns for the population.
- The available population estimates, biological, and harvest information suggest that the population is currently stable and is sustainably harvested.

INTRODUCTION

The Babbage River, situated in the Yukon Territory and within the Inuvialuit Settlement Region, flows between the British and Barn mountains and drains directly into the Beaufort Sea in Phillips Bay (Figure 1). Anadromous Dolly Varden from the Babbage River is an important cultural and subsistence resource for Inuvialuit living in Aklavik, Northwest Territories. Anadromous and stream resident life histories of Dolly Varden spawn and overwinter in the upper reach of Fish Hole Creek, a tributary to the Babbage River. The anadromous population is harvested in a mixed-stock fishery during summer along the Beaufort Sea coast in Canada and Alaska (Krueger et al. 1999). In Canada, Herschel Island and Shingle Point are important fishing locations (Figure 1). Declines in population abundance in the Big Fish River and Rat River stocks and limited critical freshwater habitat resulted in the listing of northern-form Dolly Varden in Canada as 'Special Concern' by the Committee on the Status of Endangered Wildlife in Canada (COSEWIC) in 2010. Concomitantly, an integrated fisheries management plan (IFMP) was established in order to guide the co-management of anadromous Dolly Varden in the western Arctic over the next five years (2010–2015). The implementation of the IFMP and any future evaluation by COSEWIC requires updated assessments for all Dolly Varden stocks.

ASSESSMENT

Abundance estimates (mark-recapture) and biological data were evaluated, the estimated count of Dolly Varden using a DIDSON sonar was compared to mark-recapture abundance estimates, a genetic mixed-stock fishery analysis was conducted to estimate the number of Dolly Varden from the Babbage River stock that were harvested along the coast in Canada, reported harvest was tabulated, and genetic information used to estimate effective population size (N_E).

Population Abundance

A mark-recapture approach was used to estimate population abundance. Dolly Varden were captured, tagged and/or recaptured in late September at the spawning and overwintering area of Fish Hole Creek every year between 2010 and 2014. The Petersen model with Chapman modifier was used to estimate population size with 95% confidence intervals calculated based on the assumption that the probability of recapture followed a Poisson distribution. The Poisson approximation was used because the number of recaptures among years was consistently < 50, and the ratio between number of recaptures and number tagged was < 0.1 (Seber 1982). To better meet the assumptions required to use the Petersen model, corrections were made to account for recruitment and tag loss.

Estimates of abundance for Dolly Varden ≥ 365 mm between 2010 and 2012 were similar ranging between 5,861 (95% CI = 3,967–10,799) and 6,553 (95% CI = 4,005–13,315) (Figure 2). An estimate for 2013 was substantially higher (10,356 [95% CI = 6,685–20,329]), however, the accuracy of this estimate is uncertain due to the high proportion of smaller-sized fish tagged in 2013 that were likely not as vulnerable to recapture the following year which would violate an assumption of the Petersen model and inflate the estimate of abundance. Results indicate the population was stable during 2010–2012. Estimates of abundance were also available for 1990 and 1991 (estimated using both Petersen and Bailey's triple capture models). A weir placed in the mainstem of the Babbage River (1990–1992) was used to capture, tag and recapture (1991 and 1992) fish during this period. The Petersen model abundance estimate for 1990 (18,203 [95% CI = 14,197–22,227]) was greater than the 1991 estimate (10,925 [95% CI = 9,056–12,795]) while a Bailey's triple capture model estimate (Sandstrom et al. 1997) fell between these two values (Figure 2). It is difficult to infer a decrease in abundance between 1990–1991 and 2010–2013 due to the difference in methods used for capture and recapture of tagged fish, and a lack of abundance information between decades.

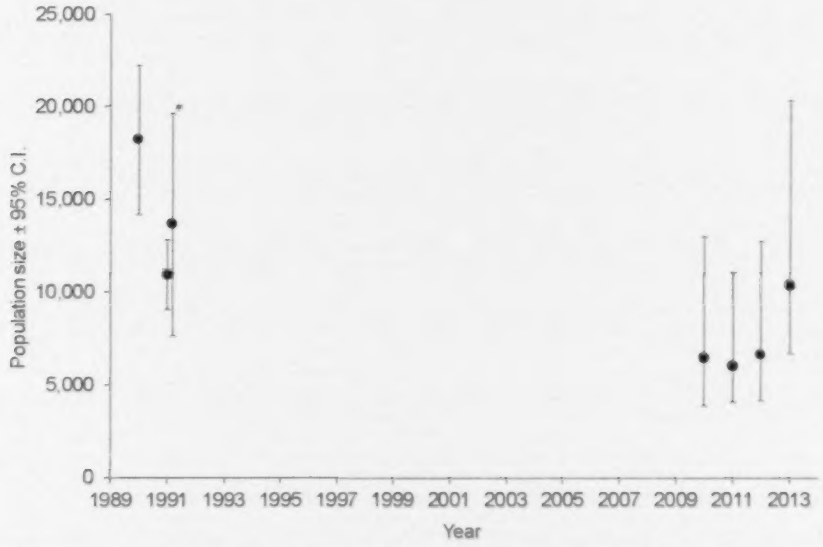


Figure 2. Population estimates for anadromous Dolly Varden from the Babbage River ≥ 365 mm for 1990, 1991, and 2010–2013 generated using mark-recapture studies (Petersen model). A second estimate for 1991 (*) was available using Bailey's triple capture model (Sandstrom et al. 1997). There is uncertainty in the 2013 estimate due to the violation of the assumption of equal catchability required by the Petersen model.

Counts of Fish

The DIDSON is a multibeam sonar designed to be used in turbid or low-light conditions. It transmits high frequency pulses of sound in the water and converts the returning echo into digital images. The standard model of the DIDSON was used to enumerate the upstream movements and record the length of fish in the Babbage River between July 22 and September 11, 2011 with the objective of estimating the number of migrating Dolly Varden. The images produced by the DIDSON did not provide the resolution to distinguish among species of fish (assumed to be predominantly Dolly Varden and Arctic Grayling [*Thymallus arcticus*]). A correction factor (32%) was applied to the count of fish ≥ 250 and ≤ 420 mm, the size range where Arctic Grayling and anadromous Dolly Varden overlap. In order to compare with abundance estimates from mark-recapture, the number of fish ≥ 365 mm was calculated. The correction factor was based on data from a 1992 weir study where 32% of the total catch was Arctic Grayling. The estimated count of Dolly Varden ≥ 365 mm ranged between 2,839 and 3,119.The majority of fish (56%) were between 300 and 500 mm. Upstream movements of fish were observed over the duration of the DIDSON deployment, however 86% of the fish detected were recorded between July 30 and August 21 when daily counts typically exceeded 100 fish.

Biological Characteristics

Dolly Varden were live-sampled at the spawning and overwintering area in Fish Hole Creek using a seine net at the end of every September between 2010 and 2014. Each fish captured in the net was identified to species and measured for fork length (± 5 mm). The life history type (anadromous or resident) was identified and, for all anadromous fish, the reproductive status was recorded ('non-spawner' or 'spawner') along with the sex if it was in spawning condition. These data were compared with data from September 1987.

Females in spawning condition ranged between 365 and 650 mm and were particularly abundant between 450 and 550 mm in length (Figure 3). Male spawners were larger in size, attaining up to 780 mm in length with a wider size distribution and a higher proportion among larger sizes (≥ 550 mm). Non-spawners were primarily distributed among sizes ≤ 475 mm, where the minimum size-at-smoltification was approximately 250 mm, therefore most non-spawners were likely juveniles with larger fish presumed to be resting adults. Non-spawners and male spawners attained similar maximum size. A bimodal distribution in length was observed for non-spawners and spawners indicating successful juvenile recruitment and a wide range of sizes in the spawning biomass. The median length of female and male spawners, and non-spawners has remained relatively consistent among years (Figure 4).The time series of length information collected at the spawning and overwintering area suggests there has been no considerable change in size structure since 1987.

Annual growth was inferred from the recapture of tagged fish between 2011 and 2014 (based on recapture of n = 27 females and n = 30 males). Males demonstrated a significantly higher rate of growth compared to females (Figure 5). Growth during 2010–2014 was higher than the 1990–1992 period (based on recapture of n = 73 females and n = 98 males), for both females and males (based on recapture of n = 73 females and n = 98 males) (Figure 5). Based on the recapture of 24 females and 17 males (in spawning condition when tagged in previous year) between 2010 and 2014, a higher proportion of females (92%) spawned in consecutive years compared to males (59%).

Between 2010 and 2014, the proportion of non-spawners encountered in the seine net varied between 32.5 and 60% (Figure 6). Female spawners ranged between 24.5 and 45.7% and in most years were 1.5 to 2 times more abundant than male spawners that accounted for between

14.2 and 30.3% of the sample. The values observed between 2010 and 2014 were similar to the data from 1987 (Figure 6).

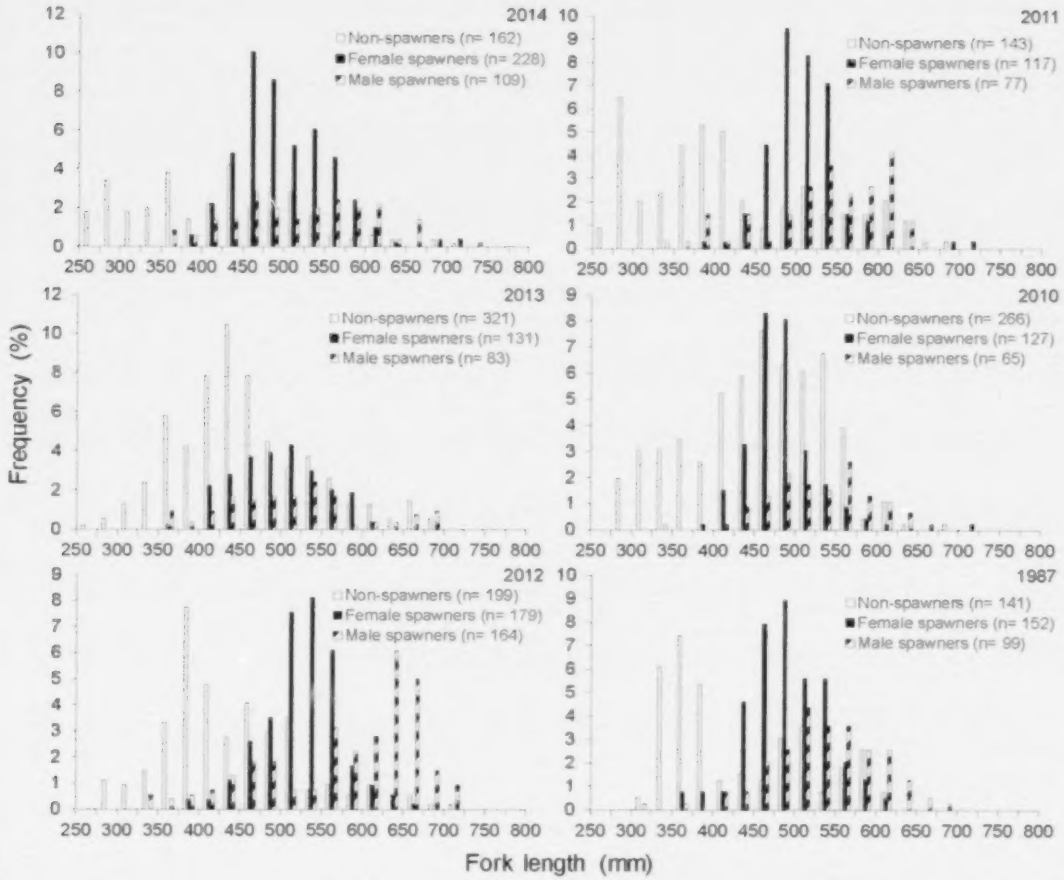


Figure 3. Length frequency distribution of Dolly Varden from the Babbage River identified as non-spawners, female spawners, and male spawners, captured using a seine net at the spawning and overwintering area in 1987, and between 2010 and 2014.

Coastal Harvest

Harvest statistics for Dolly Varden caught along the Beaufort Sea coast in the Yukon were collected by Yukon Territorial Parks (Herschel Island), the Aklavik HTC (direct reporting by harvesters), and collaborative monitoring programs (Ptarmigan Bay, Phillips Bay, Sabine Point, King Point, and Shingle Point). A comprehensive monitoring program at Shingle Point and Herschel Island between 2011 and 2014 obtained harvest information and collected biological data which included fin clip samples for genetic mixed-stock fishery analysis. Between 2009 and 2011, the reported harvest along the coast ranged between 395 and 597 Dolly Varden (Table 1).

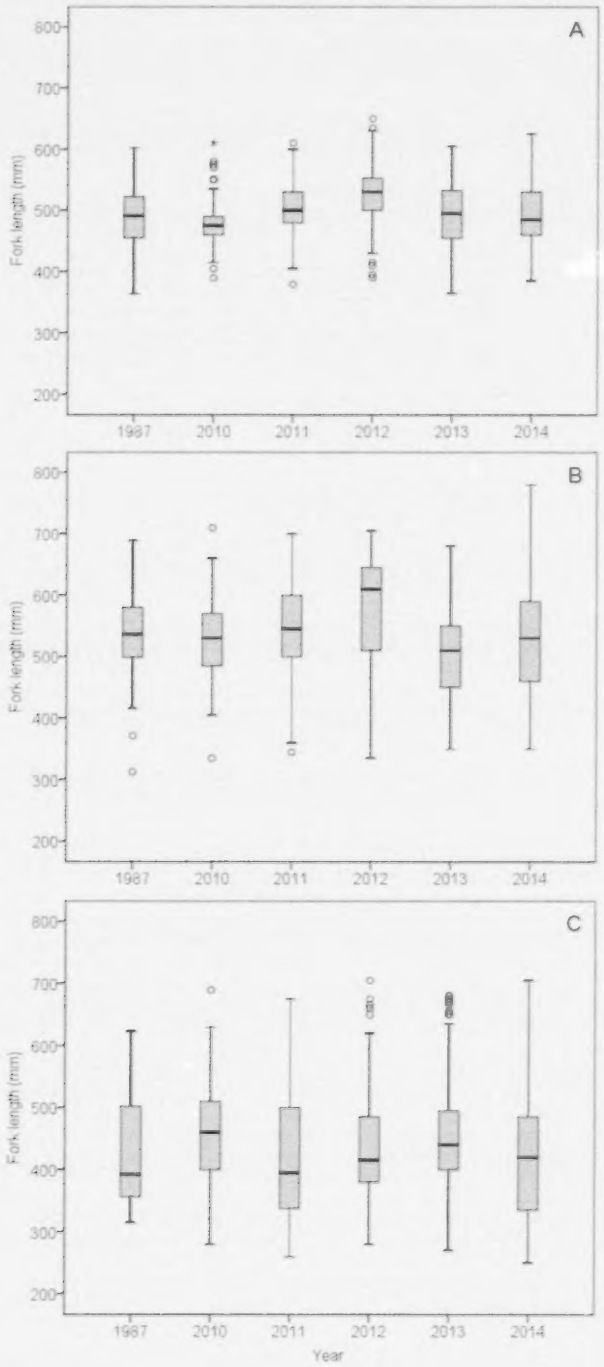


Figure 4. Fork length (median, quartiles and outliers (○, ★; values ≥1.5 x and 3 x inter quartile range, respectively)) of Dolly Varden from the Babbage River identified as A) female spawners, B) male spawners, and C) non-spawners seined at the spawning and overwintering area in 1987, and between 2010 and 2014.

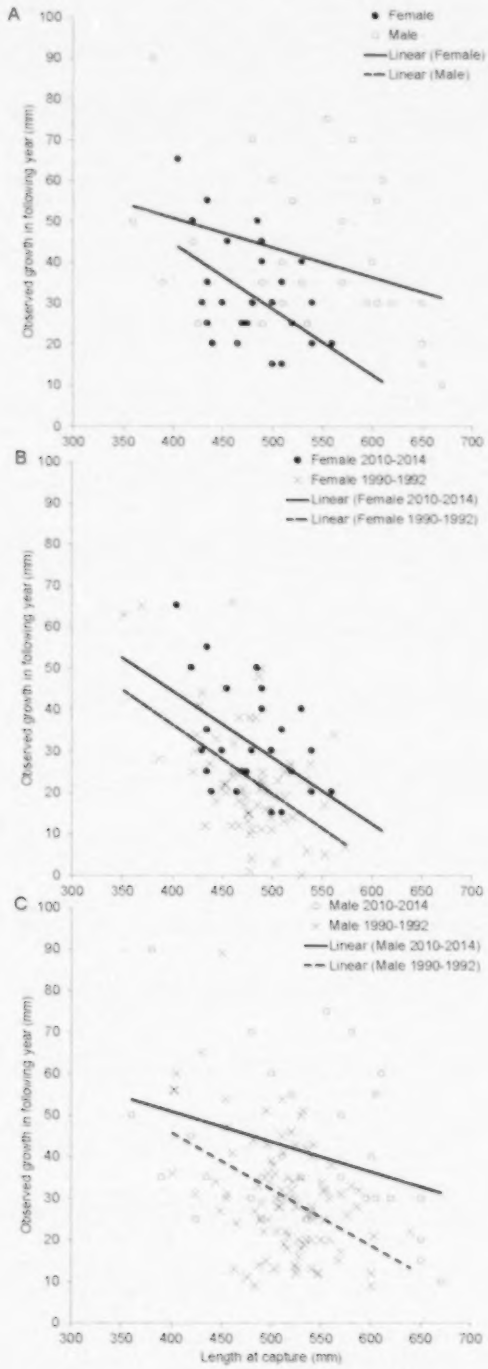


Figure 5. Observed annual growth of Dolly Varden from the Babbage River based on mark-recapture studies comparing A) males and females between 2010 and 2014, B) females between 1990–1992 and 2010–2014, and C) males between 1990–1992 and 2010–2014.

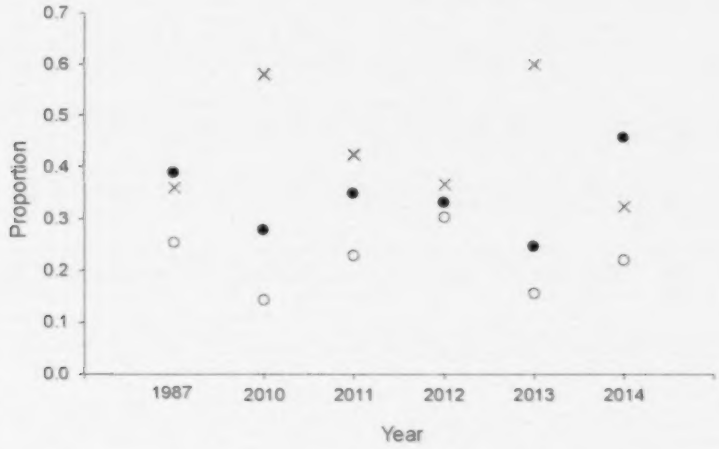


Figure 6. Proportion of anadromous Dolly Varden identified as non-spawners (X), female spawners (•), and male spawners (○) from the Babbage River captured using a seine net at the spawning and overwintering area in 1987, and between 2010 and 2014.

Table 1. Reported number of Dolly Varden harvested among locations along the Beaufort Sea coast, 2009–2014.

	Herschel Island	Ptarmigan Bay	Phillips Bay	King and Sabine points	Shingle Point	Total
2014	151	0	0	16	404	571
2013	189	12	0	19	115	335
2012	118	1	0	66	412	597
2011	129	93	0	43	193	458
2010	256	-	-	-	252*	508
2009	80	6*	2*	-	307*	395

*reported harvest values from the Aklavik HTC.
- harvest not reported

Genetic Mixed-Stock Analysis

Genetic techniques were used to examine the summer mixed-stock subsistence fishery along the Beaufort Sea coast (summer 2011–2014) to determine the contribution of Dolly Varden from the Babbage River at these locations. These results, in combination with total harvest information, were used to estimate the harvest of Dolly Varden from the Babbage River. Coastal samples were analyzed against an established genetic baseline comprised of all known anadromous Canadian Dolly Varden stocks and a subset of North Slope Alaskan stocks. Samples from Firth River, Joe Creek, and Kongakut River systems were combined into a single reporting group because it was not possible to genetically differentiate these with the information currently available. Fifteen microsatellite DNA markers were assayed from tissue samples collected between 2011 and 2014 from Herschel Island (n = 420), Ptarmigan Bay (n = 87), King and Sabine points (n = 118), and Shingle Point (n = 889). Genetic mixed-stock analysis of Dolly Varden from each coastal fishing site was performed to determine the genetic mix of fish caught in these fisheries. A conditional maximum likelihood procedure implemented in the genetic stock identification program ONCOR (Kalinowski et al. 2007) was used to report contributions from each Dolly Varden source stock to each coastal fishing site. Simulation and assignment tests verified the accuracy and confirmed the results from the mixed-stock analysis.

Results indicated that Dolly Varden from the Babbage River contributed to all reported harvesting locations along the coast between 2011 and 2014. The highest contributions were at King/ Sabine and Shingle points where the Babbage River stock contributed between 36 and 99%, and 30 and 89% to the harvest, respectively (Table 2). Shingle Point consistently produced the largest harvest of Dolly Varden from the Babbage River (range = 34–366 fish) (Table 2). The Babbage River stock contributed relatively little (range = 2–14%) to the harvest at Herschel Island (Table 2). The estimated number of Dolly Varden from the Babbage River harvested along the coast between 2011 and 2017 varied without trend, ranging between 78 and 437.

Table 2. Percent contribution (%) (± 95% CI) and number (#) (± 95% CI) of Dolly Varden from the Babbage River among multiple locations along the Beaufort Sea coast† in the Yukon 2011–2014.*

Year	Herschel Island		King and Sabine points		Shingle Point		Total
	%	#	%	#	%	#	#
2014	2 (0–4)	3 (0–6)	36 (14–64)	6 (2–10)	68 (63–73)	276 (255–293)	285
2013	14 (8–21)	27 (15–40)	88 (71–100)	17 (13–19)	30 (21–38)	34 (24–44)	78
2012	5 (1–9)	6 (1–11)	99 (95–100)	65 (63–66)	89 (85–93)	366 (350–382)	437
2011	7 (2–14)	9 (3–18)	79 (63–96)	34 (27–41)	68 (60–75)	131 (116–145)	183‡

* reported harvest (Table 1) x proportion (%)
† Ptarmigan Bay in 2011: % = 9 (3–15), # = 9 (3–14) [only year with genetic samples]
‡ count from Ptarmigan Bay included

The estimated harvest rate (total number harvested in one year divided by the Petersen model population estimate from the previous year) for the Babbage River stock based on the reported harvest in Canada was 2.8%, 7.5%, 1.2%, and 2.8% in 2011, 2012, 2013, and 2014, respectively. Unknown contribution of the stock to the harvest in Alaska results in uncertainty in the total harvest rate.

Effective Population Size

The effective size of a population (N_E) determines the rate at which genetic variability will be lost as a result of random genetic drift (the random change in allele/ genotype frequencies across generations) and is a parameter that is typically less than the census population size (N_C). Decreases in N_E typically lead to decreases in genetic variation and increases in inbreeding, which may ultimately lead to reductions in overall fitness. Therefore reductions in N_E may potentially have several adverse impacts on a population, especially those that are already small and isolated. Given that genetic variation is important for evolutionary potential, N_E should be considered when evaluating the long-term plans for population persistence and conserving biological diversity within a species.

Samples were collected at the spawning and overwintering area in three separate sampling periods (1986, 1991, and 2011). For the estimation of N_E in Dolly Varden from the Babbage River, two single-sample estimates (SS) (LDNe [Waples and Do 2008] based on linkage disequilibrium and COLONY [Jones and Wang 2010] based on sibship analyses) and two temporal-based estimates (MLNe [Wang 2001] and TempoFS [Jorde and Ryman 2007], both based on shifts in allele frequencies through time) were applied to a microsatellite DNA data set. The weighted harmonic mean when combining SS methods was 632 (-95% CI = 198) and the weighted harmonic mean when combing temporal-based estimates was 625 (-95% CI = 133; note that +95% CI could not be calculated when combining means within methods due to some results of infinity). N_E, based on the grand harmonic mean (Waples and Do 2008) of all four estimates (i.e., combing both SS and temporal-based estimates) was 627 (-95% CI = 146). The

results suggest there are no immediate conservation concerns (e.g., reductions in fitness as a result of inbreeding) for Dolly Varden from the Babbage River and long-term population persistence is likely not compromised if effective population size remains the same.

Sources of Uncertainty

There is some uncertainty whether all the assumptions of the Petersen method were sufficiently met in order to achieve a suitable estimate of population size. The expected rate of recapture of fish ≤ 425 mm was lower than observed and violated the assumption of equal catchability for all tagged fish. It is recommended that models such as Jolly-Seber and others that assume open populations be investigated in the future.

Any interpretation of a decline in population abundance since the early 1990s based on mark-recapture studies should be treated cautiously due to the different methods used for capture and recapture of tagged fish, and a lack of abundance information between decades to confidently assess any trend.

It is uncertain whether a portion of the migrating population of fish was missed prior to deployment of the DIDSON camera. In addition, the counts from the camera could not distinguish between Dolly Varden and Arctic Grayling between 250 and 420 mm in length, and a portion of the population may not have been available for enumeration (i.e., some anadromous fish may overwinter in the lower reaches while there is the possibility some fish may skip migration and remain in the upper reaches of the system).

The subsistence fishery along the coast can target different species based on fishing location and gill net mesh size. The fishery at Shingle Point mainly targets Arctic Cisco (*Coregonus autumnalis*) using small mesh gill nets (~89 mm, stretched). While Dolly Varden fisheries further west (e.g., Komakuk Beach and Herschel Island) use larger mesh sizes (~102 mm, stretched). Weather (e.g., wind speed and direction) and sea conditions (e.g., drifting ice and waves) affect the location and timing of fishing activity. The catches in the coastal fishery possibly vary in amount and stock composition due to environmental conditions that affect fish movements (e.g., migration timing, nearshore/ offshore movements). Variability in fishing effort, and the timing and location of fishing activity and sample collection may cause discrepancies in composition over seasonal and annual timeframes resulting in non-representative sampling of the coastal run.

The contribution of the Babbage River stock to the subsistence harvest in Alaska is currently unknown. Krueger et al. (1999) demonstrated the presence of the stock along the Alaskan coast using a mixed-stock analysis of allozyme data applied to samples collected in the late 1980s.

CONCLUSIONS AND ADVICE

1) The Petersen (with the Chapman Modifier) mark-recapture population estimate of Babbage River Dolly Varden ≥ 365 mm was 6,553 (95% CI = 4,005–6,553) in 2010, 5,861 (95% CI = 3,967–5,861) in 2011, 6,363 (95% CI = 4,030–12,256) in 2012, and 10,356 (95% CI = 6,685–20,329) in 2013. A violation of the assumption of equal catchability creates uncertainty regarding the 2013 estimate.

2) The population estimates from 2010 to 2013 appear lower compared to mark-recapture abundance estimates from 1990 (18,203 [95% CI = 14,197–22,227]) and 1991 (10,925 [95% CI = 9,056–12,795]), however, considerable differences in methods increase the uncertainty regarding this trend.

3) The DIDSON count for Dolly Varden ≥365 mm was estimated to be between 2,839 and 3,119 in 2011. However, there were limitations that could affect the accuracy of the count; including the timing and length of camera deployment and the challenge of distinguishing

among species. The composition of Arctic Grayling and Dolly Varden in the count of fish 365–420 mm (size overlap between species that affect comparison between DIDSON counts and mark-recapture population estimates) is unknown. Also, it was reported that some Dolly Varden overwinter in the lower reach of the river (below where the sonar was deployed) which would result in a portion of the population that was not available for enumeration. Although both the DIDSON and mark-recapture have limitations in providing estimates in the number of Dolly Varden, there was greater confidence in the results of the multi-year mark-recapture studies because there was confidence that assumptions were relatively well met and because it was possible to evaluate a temporal trend for 2010–2013. The DIDSON could be used to develop an index of abundance if this technology were to be used again in the future.

4) Genetic mixed-stock fishery analysis of samples collected along the Beaufort Sea coast between 2011 and 2014 indicate that Dolly Varden from the Babbage River were harvested at Herschel Island, Ptarmigan Bay, King Point, Sabine Point, and Shingle Point.

5) At Herschel Island and Shingle Point, locations where the majority of the harvest occurs, the estimated number of Babbage River Dolly Varden that were harvested from 2011 to 2014 (percent contribution to harvest with 95% CI in brackets) was between 3 (2% [95% CI = 0–4%] and 27 (14% [95% CI = 8–21]), and 34 (30% [95% CI = 21–38]) and 366 (89% [95% CI = 85–93]), respectively.

6) The harvest rate calculated for Dolly Varden from the Babbage River based on reported harvest in Canada, ranged between 1.2 and 7.5% between 2011 and 2014. However, imprecision of the models employed for both mark-recapture population estimates and genetic mixed-stock fishery analysis, the unknown contribution to harvest in Alaska, and the level of inter-annual variation observed in the contribution of this stock to fisheries, increases the degree of uncertainty in regards to this estimate of harvest rate.

7) The effective population size (N_E = 627 [-95% CI = 146]) suggests there are no immediate conservation concerns with respect to inbreeding and reduced fitness for the Babbage River population.

8) Fork length of anadromous Dolly Varden captured at the spawning and overwintering area at the end of September (2010–2014) were mainly distributed between 350 and 650 mm, with a higher proportion of males among sizes > 550 mm compared to females. A bimodal distribution in length was observed for non-spawners (mainly juveniles between 350 and 450 mm) and spawners (mainly between 450 and 600 mm) indicating successful juvenile recruitment and a wide range of sizes in the spawning biomass. The length data, which are a useful biological indicator of stock status, suggest no considerable change in length structure since 1987.

9) The composition of anadromous spawners captured between 2010 and 2014 ranged from 40% to 67.5% with female spawners generally one and a half to two times more abundant than males. The high proportion of spawners combined with the length structure data suggests that productivity/ reproductive capacity of the anadromous component of the population has been maintained.

10) Growth (change in length from one year to the next) information derived from the mark-recapture studies revealed males grew faster than females (based on recapture of n = 29 females and n = 30 males between 2011 and 2014) and that growth has increased since the early 1990s (based on recapture of n = 73 females and n = 98 males between 1991 and 1992).

11) Biological data from the mark-recapture studies indicated females spawned in consecutive-years more often than males. Based on 41 samples of Dolly Varden (n = 24 females and n = 17 males), 92% of females and 59% of males tagged as spawners were recaptured in spawning condition the following year.

12) The available population estimates, biological, and harvest information suggest that the population is currently stable and is sustainably harvested.

13) In order to better evaluate how the reported harvest, which is an important metric used in the assessment of the Babbage River population, varies among years, it is suggested to gather local knowledge/ observations in association with the coastal harvest data to better understand how environmental conditions affected catches and effort in the fishery.

SOURCES OF INFORMATION

This Science Advisory Report is from the meeting held on February 9-10, 2015 on the Assessment of Dolly Varden, *Salvelinus malma malma*, from the Babbage River, Yukon Territory. Additional publications from this meeting will be posted on the DFO Science Advisory Schedule as they become available.

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